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Original Article

# The stability of tetracalcium phosphate/titanium implants: A short-term follow-up study

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**KEYWORDS**
Tetracalcium phosphate;
Surface modification;
Resonance frequency analysis;
Implant stability

*Background/purpose:* Bioceramic tetracalcium phosphate (TTCP) is used as a surface modifier on the implant surface and the clinical studies on this surface modification are still limited. The objective of this clinical study was to investigate short-term implant stability of titanium implant surfaces being modified through sandblasting and acid etching (SLA), followed by TTCP sintered bioceramic anchoring.
*Materials and methods:* A total of 20 patients who had single tooth space were included in this study. Surface modification by SLA plus with TTCP on Ti implants with a diameter of 4.0 mm and lengths of 10 and 11.5 mm were placed. Implant stability quotient (ISQ) value was measured immediately (ISQ0) and one month (ISQ1), two months (ISQ2), three months (ISQ3), and four months (ISQ4) after implantation. Subgroup analysis was defined to location (maxilla, mandible) and bone density (soft or hard bone). Statistical analysis was performed using Friedman test and Mann–Whitney U test.
*Results:* The mean ISQ values with standard deviation at the different time points of ISQ0 to ISQ4 were 60.03 ± 14.12, 53.48 ± 15.24, 58.91 ± 14.43, 63.14 ± 12.22, and 63.50 ± 13.61, respectively. The results showed significant differences between the ISQ1 and ISQ3 groups and between the ISQ1 and ISQ4 groups. On the other hand, there was no statistical differences between the maxilla and mandible as well as between soft and hard bone types in all implant groups.

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*Conclusion:* TTCP/titanium implant showed favorable stability in short-term ISQ values over 4 months. The locations and bone types demonstrated no effect on implant stability.


## Introduction

Dental implants are constantly evolving in order to provide better effective treatment outcomes. The chemical composition and surface treatment of implant materials can affect early bone healing after implant placement due to implant-associated protein adsorption and conformational changes.[1—6] With the well-known concept of sandblasting and acid etching (SLA) surface treatment, the titanium machine surface is modified by coarse grit-blasting using 0.25—0.5 mm corundum grit at air pressure of five bars, followed by acid-etching.[7] Recently, the newly developed titanium implant surface treated with SLA and anchored with sintering tetracalcium phosphate (TTCP) can promote osseointegration by forming a mechanical granular interlocking film. About 70% of the minerals in human bone are calcium phosphates (CaPs), therefore, the CaPs on the implant surface can conduct and promote bone healing, thereby causing the biointegration of the implant.[8] $Ca_4(PO_4)_2O$ is the chemical formula for TTCP with a high atomic Ca/P ratio of 2.0 in a calcium phosphate compound. When TTCP is dissolved in an aqueous solution, a large amount of calcium cations ($Ca^{2+}$) and phosphate anions ($PO_4^{3-}$) are spontaneously generated. Furthermore, in addition to ion release, the residual phase of TTCP is generally converted to hydroxyapatite (HA) with the molecular formula $Ca_{10}(PO_4)_6(OH)_2$ and appropriately affects early bone formation and healing.[9,10] HA is a naturally occurring calcium phosphate mineral at neutral pH with good biocompatibility and an excellent candidate for bone repair with a Ca/P atomic ratio of 1.67. The SLA plus with TTCPs on implant surfaces can accelerate and mineralize progenitor bone cell in *in vitro* study.[11] *In vivo* study showed that CaP implants can regenerate and decrease the time required for osseointegration. TTCP derivation has been shown to be almost entirely resorbed 24 weeks after implantation.[12]

One of the important factors of implant success is implant stability. Osseointegration is related to implant stability in many aspects.[13] At any stage of therapy or during follow-up examinations, the resonance frequency analysis approach can provide therapeutically useful information on the state of the implant—bone interface. Implants with high implant stability quotient values are successfully integrated, whereas low or decreasing implant stability quotient values can show continuous failure of implants or marginal bone loss. There are many factors that affect the stability of implants, such as implant materials related to strength and resilience, implant characteristics of geometric design, and the combination of implant site and bone quality.[11—13] Among them, the most critical factor is the interface and contact area relationship between the bone tissue and the implant. The aim of this study is to clinically investigate and compare the short-term implant stability in different time period of titanium implant surface treated by SLA plus with TTCP by measurement of the implant stability quotient (ISQ).

## Materials and methods

This prospective cohort study was approved by the Human Research Ethics Committee of the Faculty of Dentistry Chulalongkorn University (study code: HREC-DCU 2018—114) and registered at the Thai Clinical Trials Registry database (study code: TCTR20190423001). All patients participating in this clinical trial were voluntary and have signed informed consent.

All surgeries were performed at Department of Oral and Maxillofacial Surgery, Chulalongkorn University between May 2019 and January 2020 by one surgeon. The 20 patients who followed the inclusion criteria: (a) single tooth space on upper or lower arch, and require single restoration, (b) adults aged 20—75 years. The exclusion criteria were as followed: (a) uncontrolled diabetes, and chronic diseases, (b) cerebrovascular accident patients or the patients taking anti-rejection medicine and osteoporosis drugs for long-term, (c) the case with filled bone graft, (d) the case of other missing teeth, (e) the case of dental bridge or dentures equipment required, (f) the health condition is not well after health education and physical therapy.

Patients were examined at the first visit for screening by periapical film to include in this study. Impression was taken with irreversible hydrocolloid for making diagnostic model. The conventional acrylic stent with radiopaque marker was produced and inserted, then a cone-beam computed tomography image was done using 3D Accuitomo 170 machine (J. Morita Inc., Kyoto, Japan).

In the surgical stage, the surgery was performed under local anesthesia. Full thickness mucoperiosteal flap was elevated after sulcular and crestal incision. AnkerII dental implant system (Alliance Global Tech Inc., Kaohsiung, Taiwan) with diameter of 4.0 mm and length of 10 and 11.5 were selected in this study. Resonance frequency analysis (RFA) presented as ISQ (Osstell, Gothenburg, Sweden) value was measured immediately after implants placement (ISQ0). Implants that insertion torque less than 25 Ncm were excluded. Healing abutments that higher than gingival margin were inserted. Briefly, the surgical procedure was shown in Fig. 1.

The postoperative medications were administered included systemic antibiotics (amoxicillin one gram, twice a day) and analgesic (mefenamic acid 500 mg, three times a day) for five days. In patients allergic to penicillin, clindamycin 300 mg was administered three times a day. Periapical film was taken immediately after the surgical intervention.

Two weeks after surgical intervention, the patients were followed up for checking wound healing at implant sites. Patients was followed up for examining the implant sites, taking periapical radiographs and RFA measurements on one month (ISQ1), two months (ISQ2), three months (ISQ3), and four months (ISQ4). Subgroup analysis was defined to location (maxilla, mandible) and bone density (soft bone: bone type I, II; hard bone: bone type III, IV).[14] Four months after surgical intervention, the patients were referred to prosthodontist for supra-structure construction.

Statistical analysis was using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA). The normality of data distribution of ISQ was calculated using Shapiro–Wilk test. ISQ between different time points were compared using Friedman test. Mann–Whitney U test was using to compared mean ISQ between different bone type and location. *P*-value $< 0.05$ was considered as statistically significant.

**Table 1** Patients' demographic data.

| Variable | Total (N) |
|---|---|
| Implant | 20 |
| Subject | 20 |
| Gender | |
| Male | 6 |
| Female | 4 |
| Implant size | |
| 4 × 10 mm | 13 |
| 4 × 11.5 mm | 7 |
| Location | |
| Maxilla | 9 |
| Mandible | 11 |
| Bone type | |
| soft | 11 |
| hard | 9 |

## Results

Twenty patients received single implant placement with no bone graft. All samples included 6 males and 14 females with mean age of 48.05 years (range 30–74). Locations of implant were maxilla (9 patients) and mandible (11 patients). Bone types of patients were soft bone (11 patients) and hard bone (9 patients). All implants achieved 25 Ncm insertion torque or more. The implant size and basic information of the patients were detailed in Table 1.

The mean ISQ values and standard deviations at different time points were 60.03 ± 14.12 (ISQ0), 53.48 ± 15.24 (ISQ1), 58.91 ± 14.43 (ISQ2), 63.14 ± 12.22 (ISQ3), and 63.50 ± 13.61 (ISQ4). Statistical analysis showed that there were significant differences between ISQ1 and ISQ3 groups ($p = 0.027$) and ISQ1 and ISQ4 groups ($p < 0.001$). However, the others ISQ values were no statistically significant differences between groups as shown in Fig. 2.

There were no statistically significant differences in the paired ISQ0, ISQ1, ISQ2, ISQ3, ISQ4 values, when the implants were placed either in the maxilla or in the mandible (Fig. 3). The *p*-values of ISQ0 to ISQ4 were 0.849, 0.790,

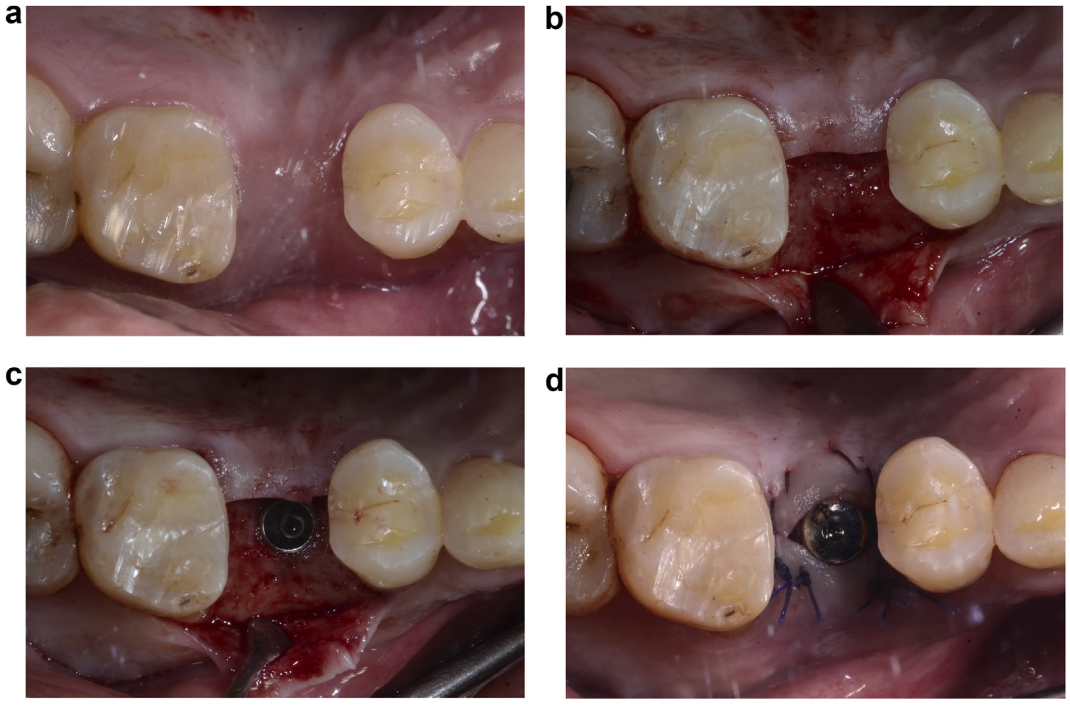


**Fig. 1** Representative images of implant placement (a) Pre-operative (b) Full-thickness flap operation (c) Implant placement (d) Suturing.


**Fig. 2** The overall mean ISQ values measured at each time points.

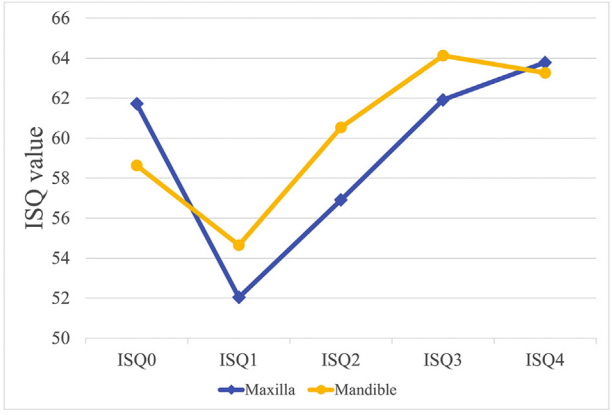


**Fig. 3** The mean ISQ values of different locations measured at each time points.

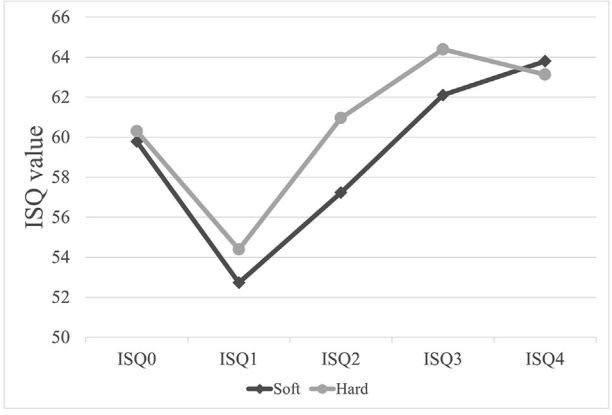


**Fig. 4** The mean ISQ values of different bone types measured at each time points.

0.648, 0.732 and 0.970, respectively. Moreover, no statistically significant differences in the paired ISQ0, ISQ1, ISQ2, ISQ3, ISQ4 values were found, when the implants were placed either in the soft bone or in the hard bone (Fig. 4). The *p*-values of ISQ0 to ISQ4 were 0.676, 0.909, 0.676, 0.543 and 0.970, respectively.

## Discussion

Resonance frequency analysis (RFA) is extensively utilized procedures in clinical practice for assessing implant stability.[15,16] The RFA technique measures implant stability by continuously exciting the implant interface through dynamic vibration analysis (piezo effect). The ISQ measured by the RFA technique is calculated on a scale of 1–100, with a range of 60–70 indicating successful dental implantation.[17]

Titanium implant containing CaPs is an alternative modification for improved osseointegration.[12] The efficient incorporation of cell-secreted organic and inorganic substances on the implant surface is the primary mechanism for subsequent function and biological efficacy, resulting in osseointegration. The surface of the bioceramic TTCP-modified titanium implants released a large amount of $Ca^{2+}$ cations to promote the growth of epitaxial apatite, thereby inducing binding to the extracellular matrix proteins. It is well known that nano-films of $TiO_2$ with thickness reaches 10 nm are spontaneously formed on the surface of titanium. In addition, $Ca^{2+}$ ions show high affinity for TiO2, so they are largely adsorbed on the oxide layer on the surface of titanium, adhering extracellular matrix proteins and induces migration of progenitor bone cells. In this study, we investigated the clinical application in term of stability of CaPs implant with ISQ. The results showed statistical differences between groups of ISQ1 and ISQ3 and groups of ISQ1 and ISQ4, in accordance with previous studies that ISQ values decreased significantly after three to four weeks of implant placement and subsequently increased after 5–8 weeks.[18–20]

Some studies investigated the effect of implant location to ISQ.[21,22] The results showed that there were no significant different between mandible and maxilla which also showed the same results as our study. Nevertheless, Bischof et al., 2004 reported that ISQ value of mandible was higher than maxilla.[23]

Alsabeeha et al., 2010 showed that the primary stability of implants measured using RFA was not affected by bone quality, which is consistent with our study.[24] On the contrary Hieu et al., 2013 evaluated RFA in magnesium ion-incorporated titanium implant at 0, 2, 4, 8, and 12 weeks after implant placement, they found significant different in type II and type IV bone.[25] Barewal et al., 2003 investigated RFA in SLA surface implants and found significant difference between groups for each bone type at three weeks post-healing. Nevertheless, five weeks after implant placement, there were no significant differences in all bone types.[18] Thongborisoot et al., 2017 compared the implant stability between SLA and SLA active surfaces, the results demonstrated that the SLA active might play an important role in type IV bone due to the higher significant differences of ISQ than SLA surface after 1–2 months of placement. However, both groups had RFA values higher than 60 after 1 month.[26] Thus, the titanium implant containing CaP achieve sufficient stability as the ISQ of both soft and hard bone types reached 60 or above after 3 months.

The limitations of this study are the relatively small sample size and minimal number of subjects involved. Large sample sizes of other implant surface modifications with stability should be compared in further studies. Moreover, the long-term follow up is required for TTCP/titanium implant.

In accordance with this study, titanium implant surface treated by SLA plus with TTCP achieved desirable stability. The ISQ value was decreased at the one month after implant placement, subsequently it was increased over the initial stability. Moreover, this TTCP surface implant can be apply at any locations and bone types.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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